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OMSAPC ADVISORY CIRCULAR

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR AND WASTE MANAGEMENT

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Subject: Measurement of Vehicle Frontal Area and Protuberance

I. Purpose

The purpose of this advisory circular is to provide general guidance on the measurement and calculation of the basic vehicle frontal area for light-duty trucks, and the vehicle reference frontal area and protuberance frontal area for light-duty vehicles as they apply to the road load power determination formulas contained in 40 CFR 86.129-79(a) and (c). Guidance is also given on what vehicle components are to be included in each of the different categories of frontal area.

II. Background

A. On December 28, 1976 (41 FR 56316), EPA published regulations which included procedures for determining light-duty truck road load horsepower settings based upon the frontal area of these vehicles. These procedures are effective beginning with the 1979 model year, or may be used at the manufacturer's option beginning with the 1978 model year.

B. On September 12, 1977 (42 FR 45641), EPA published similar regulations for light-duty vehicles and passenger automobiles effective beginning with the 1979 model year.

C. The regulations require that EPA approve in advance any method used by a manufacturer to calculate a frontal area.

III. Applicability

The provisions of this advisory circular are effective immediately and are applicable to 1979 and later model year light-duty vehicles, light-duty trucks, and fuel economy data vehicles. The provisions of this circular also apply to any manufacturer who chooses to optionally certify his 1978 model year heavy-duty vehicle or light-duty truck under the provisions of 40 CFR 86.078-1(b).

IV. Basic Vehicle Frontal Area

A. The term "basic vehicle frontal area" pertains to light-



duty trucks. It is the area of the orthogonal projection of the vehicle onto a plane perpendicular to both the longitudinal plane of the vehicle and the surface upon which the vehicle is positioned. The term "B" is used to refer to the sum of the basic vehicle frontal area and the additional frontal area of mirrors and all items of optional equipment exceeding 0.1 ft^2 which are anticipated to be sold on more than 33 percent of the car line (Ref. 40 CFR 86.129-79(a)).

B. The additional frontal area of optional equipment will be treated as follows:

1. If the option, when installed on the vehicle, is visible in the front orthogonal view of the vehicle, and the area that is visible exceeds 0.1 ft^2 , then that area including the initial 0.1 ft^2 will be added to the basic vehicle frontal area. All options which meet the criteria of IV.A and IV.B.1 shall be listed in the manufacturer's Part I application in Section VIII of the recommended application format. For each option listed, the manufacturer must state the frontal area of the option and the incremental addition to road load power that results from including the frontal area of the option in the primary calculation of road load power where only the basic vehicle frontal area is considered (see 40 CFR 86.129-79(a) for calculation of road load power). In those cases where a particular option is available in different sizes (e.g., mirrors, luggage racks) the added area and horsepower of the option having the greatest frontal area for the car line will be used to determine the road load power setting for all test vehicles in the car line.

2. In the case of mutually exclusive standard and optional equipment, such as a sun roof and a luggage rack, the item with the largest frontal area will be used to compute the value of "B."

3. In the case of mutually exclusive options, such as outside mirrors, the total sales of all the various configurations of the same generic option will be used when comparing the sales of the option with the 33 percent sales criterion of IV.A. The actual option which is to be installed on the vehicle when the value of "B" is determined will be the one with the greatest frontal area of the various configurations.

C. For the purpose of calculating frontal area, four-wheel drive vehicles will be considered to be a separate car line from the two-wheel vehicles from which they might be derived. This provision is applicable even if for the manufacturer's purposes he considers four-wheel drive to be an item of optional equipment. Therefore, four-wheel drive is not to be considered an item of optional equipment.

D. For incomplete vehicles, i.e., cab and chassis models, the basic vehicle frontal area and resultant road load power will be calculated using the largest frontal area which the manufacturer will allow to be installed on his chassis.



1. The frontal area will be the same as that specified by the manufacturer in compliance with 40 CFR 86.079-35(d).

2. This information shall be included in the manufacturer's application for certification along with the other information requested in Sections IXa and IXb of the recommended application format.

V. Vehicle Reference Frontal Area

A. The term "vehicle reference frontal area" pertains to light-duty vehicles. It is the area of the orthogonal projection of the vehicle, including tires and suspension components but excluding vehicle protuberances, onto a plane perpendicular to both the longitudinal plane of the vehicle and the surface upon which the vehicle is positioned.

B. Items which should be included in the vehicle reference frontal area are:

1. Front air dams,
2. Body side moldings,
3. Fender flares,
4. Wheel covers, if visible in the orthogonal projection, and
5. Bumpers, if visible in the orthogonal projection.

C. Items which extend forward or rearward from the vehicle, such as bumper extensions, fuel filler necks, driving lights and license plate holders should only be included in the calculation of the basic reference area if they increase the orthogonal frontal area of the vehicle.

VI. Protuberance Frontal Area

A. As stated in 40 CFR 86.129-79(c)(2)(i), a protuberance is defined as any fixture attached to the vehicle protruding more than one inch from the vehicle surface and having a projected area greater than 0.01 ft². If a fixture does extend more than one inch, the entire area of the protuberance, including the initial one inch of extension, will be calculated. The total protuberance frontal area shall be the sum of the areas of all fixtures of standard equipment, and all items of optional equipment which are expected to be sold on more than 33 percent of the car line, which meet the above criteria.

B. Items which should be considered as protuberances, if they meet the criteria in VI.A, are:

1. Door handles,
2. Hood ornaments,
3. Antennas, front or rear mounted,
4. Air deflectors, such as those offered on station wagon models to reduce dirt build-up on the rear window,
5. Outside mirrors,



6. Truck mounted luggage racks--on fastback shaped vehicles only,
7. Roof mounted luggage racks, and
8. All rear deck spoilers. The entire area should be used including any portion which might be flared into the sides of the rear fenders. If any portion of the spoiler is also visible in the front orthogonal view used to determine the vehicle reference frontal area, that area should only be considered once, as a protuberance and should not be included in the vehicle reference frontal area.

C. If an item is not included as a protuberance because of the criteria in VI.A, it need not be included in the calculation of protuberance frontal area. However, if it is expected that more than 33 percent of the car line sold will be equipped with an item of optional equipment which is not considered to be a protuberance according to VI.A, and the item is visible in the front orthogonal view, then the area of this item shall be included in the vehicle reference frontal area. The specific examples in VI.B are not intended to be all-inclusive, however. It is the manufacturer's responsibility to determine if his vehicles include protuberances in addition to those in VI.B.

1. For each option listed, the manufacturer must state the protuberance frontal area of the option and the associated protuberance power determined by Table I of 40 CFR 86.129-79(c). In those cases where a particular option may be available in different sizes (e.g., mirrors, luggage racks), the added area and protuberance power of the option having the greatest frontal area for the car line will be used to determine the road load setting for all test vehicles in the car line.

2. In the case of mutually exclusive standard and optional equipment, such as a luggage rack and air deflector, the item with the largest frontal area will be used to compute the protuberance frontal area.

3. In the case of mutually exclusive options, such as outside mirrors, the total sales of all the various configurations of the same generic option will be used when comparing the sales of the option with the 33 percent sales criterion of VI.A. The actual option which is to be installed on the vehicle when the dynamometer power absorber setting "Hp" (Ref. 40 CFR 86.129-79(c) (2)(i)) is calculated will be the one with the greatest frontal area of the various configurations.

VII. Fastback Roofline Criteria

The definition of a fastback roofline is one which is at an angle of 20° or less from the horizontal. The regulations, 40 CFR 86.129-79(c)(2)(i), do not provide for any tolerance around this angle. However, if a manufacturer believes that this criterion does not accurately evaluate the drag characteristics of a vehicle's roofline, he may determine the vehicle's road load horsepower using an approved alternate procedure.



VIII. Methods for Calculating Vehicle Frontal Area

A. The techniques described in this section are applicable to the measurement of basic vehicle frontal area, vehicle reference frontal area, and protuberance frontal area.

B. The regulations require that EPA approve in advance the method(s) the manufacturer intends to use to calculate his frontal areas.

C. The manufacturer should request approval of his method as part of his application for certification or fuel economy program submission. Any method approved for the manufacturer for use in the certification program is also approved for use in that manufacturer's fuel economy program. One method which will be approved in all cases is the attached EPA "Recommended Practice for Determination of Vehicle Frontal Area."

D. Examples of methods EPA has found to be technically valid are:

1. Long-range photography and a direct measurement by planimetry.
2. Scan the outline of the vehicle with a light source and photo-electric cell.
3. Trace the outline of the vehicle with a mechanized arm.
4. A composite of engineering drawings.

For the last two techniques, care should be taken to include suspension components and underbody projections.

E. The manufacturer should completely describe his method for measuring frontal areas. The description should include:

1. If a photographic method is used:

a. The distance from the camera to the station of largest cross-sectional area, A_R , on the vehicle. This distance should be at least one-hundred yards (100 m). A known standard area (reference frame) should be positioned at this station, A_R , (Ref. EPA "Recommended Practice for Determination of Vehicle Frontal Area").

b. The distance from A_R to any other station at which a projection of significant frontal area (i.e., 0.1 ft^2) extends outside of the area contained within A_R , and the distance to any other known standard areas. Because of perspective distortion, the use of a single reference area underestimates areas behind the reference area and overestimates areas ahead of the reference area when planimetered.

(1) If significant frontal area occurs at cross sections of the vehicle other than at the location of the reference frame and protrudes outside of the area contained within A_R , and is behind the reference frame, an additional known standard area shall be located at the protruding region.



(2) The manufacturer is not required to use additional known standard areas at protruding regions ahead of the reference frame, but he may at his option.

2. If the area is derived from the manufacturer's drawings or from a mechanized arm, the manufacturer should explain:

- a. How the point of largest cross-sectional area, A_R , was determined.
- b. How it was determined if other body projections such as fender flares, side mounted spare tires, or mud flaps extend outside of the area included by the body at its maximum cross-section.
- c. How the areas of suspension components and underbody projections were measured.

F. The manufacturer may use the same frontal area for all models within a body type, as defined in 40 CFR 86.078-2, provided they meet the following criteria with all requisite optional equipment installed:

1. For light-duty vehicles the vehicle reference frontal area is within 0.5 ft^2 and the protuberance frontal area is within 0.3 ft^2 .

2. For light-duty trucks the basic vehicle frontal area plus additional frontal area is within 1.0 ft^2 .

Mobile Source Air Pollution Control

Attachment

Recommended Practice for Determination of Vehicle Frontal AreaI. Purpose

This recommended practice specifies a technique for determining light-duty vehicle reference frontal area and light-duty truck basic vehicle frontal area by using a photographic method. The procedure involves preparing and photographing a vehicle and the determination of the frontal area by planimetry of the resulting photograph. If light-duty vehicle reference frontal area information or light-duty truck basic vehicle frontal area information is available from engineering drawings or other appropriate methods, such as light projection tracings of the vehicle silhouette, these sources of frontal area information may be directly analyzed by the methods of Section IV.

II. Equipment

The basic equipment required is an appropriate facility, a camera, a well defined known standard area which will be included in the photograph and the vehicle. Other auxiliary or assisting equipment which may be required or desirable are also discussed in this section.

A. The Facility

The required facility is a large room or area in which the vehicle can be photographed from a distance of approximately 300 ft. (100 m). The location where the vehicle is placed should be level and large enough for convenient placement and alignment of the vehicle. Any difference in elevation between the vehicle location and the camera location must be known. An indoor facility is preferred, to minimize any image distortions caused by thermal gradients in the air between the vehicle and the camera. If an indoor facility is not available it is suggested that the photographs be taken at a time of minimum thermal gradients, such as early morning or overcast days.

The facility floor in the region of the vehicle location should be marked to provide convenient alignment of the vehicle, the known standard area and the camera. It may be convenient if a sight line is provided on the floor of the facility between the vehicle and the camera location.

B. Camera and Related Equipment1. Camera

The camera should be a high quality single lens camera with a long focal length telephoto lens. The suggested camera is a 35 mm single lens reflex with a telephoto lens having a focal length of about 1000 mm.

2. Tripod(s)

At least one tripod to support the camera is required. The use of two tripods is recommended, one to hold the lens and the other attached

to the camera. All tripods used should be sturdy and capable of sufficient vertical adjustment that the middle of the lens may be positioned at half of the overall height of the vehicle.

3. Shutter release

A remote shutter release should be used to avoid camera vibration during the photographic exposure. An air bulb release is preferred however a cable release is acceptable. The use of an internal camera "self timer" shutter release is also acceptable.

4. Film

The film must be an extremely fine grain black and white film.

5. Lights

Lights must be provided which will supply sufficient illumination of the vehicle including the undercarriage, the known standard area, and the backdrop.

6. Backdrop

The backdrop must be of a contrasting color and large enough to completely surround the vehicle in the camera view finder. Medium gray will suffice for most vehicle colors. Alternately a backdrop of varying contrasting squares or strips may be used.

7. Light meter

A light meter is preferred for efficiently determining the lighting arrangement and the camera exposure. Trial and error or multiple exposures are, of course, acceptable.

C. The Known Standard Area

Some well defined known standard area must be included in the photograph. The preferred approach is to position a frame of known size bridging the vehicle at the cross section of maximum area. The frame should be just large enough to encompass the desired vehicle. This allows selection of a lens of maximum focal length which will produce the maximum image size on the film. For light-duty vehicles a suggested size for this known area frame is 6.5 ft. (1.98 m) high (from the floor to the cross bar) by 8 ft. (2.44 m) wide. For light-duty trucks the known area frame must be appropriately sized to accommodate the particular vehicle under consideration.

For vehicles which require the cross bar to be higher than 7 ft. (2.13 m) the distance from the vehicle to the camera will have to be greater than the recommended 300 ft. (100 m) in order to contain the frame within the format of a 35 mm camera when using a 1000 mm focal length lens.

The midpoint of the vehicle wheelbase is a reasonable estimate of the location of the vehicle cross section of maximum area for light-duty vehicles and vans. For light-duty trucks the midpoint of the truck cab door is a convenient estimate of the location of this cross section of maximum area. If significant vehicle frontal area occurs at cross sections of the vehicle other than at the location of the reference frame, for example protruding fenders on dual drive wheel trucks, care must be taken to avoid perspective distortion of this contribution to the total frontal area. In this instance it is required that additional known standard areas be located at the protruding region. Alternately the known standard area can be moved and two photographs taken. One photograph is then used to determine the frontal area of the general body and the second to determine the area of the protruding regions.

The method described for determining the frontal area of protruding regions of the vehicle body may also be used to measure the frontal area of vehicle protuberances. In this instance a known standard area should be placed at the location of the protuberance. The camera should be equipped with a longer focal length lens, or the camera should be moved closer to the vehicle to insure a reasonable image size is obtained on the photographic film. In any case, the distance from the camera to the protuberance should be at least 30 ft. (10 m).

D. The Vehicle

The vehicle must contain all standard equipment for that model and all optional equipment which will influence frontal area and be sold on more than 33% of the vehicles within the car line. A car line is defined in 40 CFR 600.002 as a group of vehicles within a make or car division which has a degree of commonality in construction (e.g., body, chassis). For the purposes of frontal area measurements four wheel drive and two wheel drive vehicles are to be treated as different car lines. In addition, car line does not consider any level of opulence or decor.

As photographed, the vehicle must have a full fuel tank and 300 lbs (136 kg) of ballast distributed evenly between the two front seating positions. The vehicle must conform to the manufacturer's specifications in the following respects.

1. Trim heights, front and rear.
2. Tire pressures.
3. Wheel alignment.

E. Miscellaneous

The following miscellaneous items are often useful.

1. Plumb bob - This is used to align the vehicle center line with the sight line.
2. Floor jacks (with casters) - One or two of these are used to position the vehicle and to align it with the sightline.
3. Communications - Radio or telephone communications between camera and vehicle are more convenient than hand signals.

4. Message board - It is desirable to include a message board to identify the vehicle in the vehicle photograph. The vehicle identifiers should be in block letters approximately 3 in (70 mm) high.

III. Procedure

A. Vehicle Preparation

1. Place the vehicle, as described in II-C and D, as nearly as possible in the desired final position. That is, centered on the sightline and the appropriate distance from the camera.
2. Use the floor jacks to move the vehicle to its final position. The vehicle center line at each end of the vehicle should be within 1/2 in (15 mm) of the sightline and both centerlines must fall on the same side of the sightline to minimize error.
3. Place the standard area frame around the vehicle at the point of the maximum vehicle cross-sectional area.
4. The camera shall be located at the same elevation as the mid-point of the overall vehicle height. Care should be taken when adjusting the camera height above the floor to correct for differences in floor elevations between the vehicle location and camera location.

B. Photographic Preparation and Exposure

1. Set the camera and lens up so that the front lens element is at the desired distance from the vehicle, the lens is level, and the center of the lens is at a height equal to one-half of the overall height of the vehicle. Any necessary corrections must be made for differences in elevation between the vehicle and camera sites.
2. Choose a backdrop color to provide maximum contrast with the vehicle. Illuminate the vehicle, backdrop, standard area frame, and vehicle under-carriage in order to achieve maximum contrast between the vehicle and backdrop.
3. Using the camera viewfinder, insure that the wheels are straight ahead.
4. Examine the viewfinder image or take test shots to insure that the entire vehicle and standard area frame are imaged on the film.
5. Measure the light on the vehicle and backdrop and calculate the exposure required.
6. Film Exposure - If possible, use a mirror lockup to minimize camera vibration and an air bulb shutter release. Use an aperture as small as practical to increase depth of field. The field of focus should include the entire vehicle if possible. Bracket the calculated shutter speed to insure the best possible exposure.

IV. Analysis

A. Developing and Printing

Develop the film and enlarge the best exposure so that the maximum image size of the vehicle and standard area frame which can be printed on an 8 in by 10 in print is obtained.

B. Planimetry

Planimeter the image of the standard area frame on the print. Planimeter the vehicle image. The visible undercarriage components must be included, but air spaces may be subtracted. For light-duty vehicles only, it is not necessary to include vehicle mirrors, radio antennae, or other protuberances in the measurement of the vehicle reference area. Protuberances may be photographed and planimetered separately using the same technique used to determine the vehicle reference area.

C. Area Calculation

Calculate the vehicle frontal area by the following equation:

$$V = \frac{vS}{s}$$

where

V = the vehicle frontal area

v = the area of the photographic image of the vehicle

S = the area of the standard area frame

s = the area of the photographic image of the standard area frame.